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Tall Fescue and Smooth Bromegrass. II. Effects of Nitrogen Fertilization and Irrigation Regimes on Quality[1]

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ABSTRACT

Both quantity and quality must be considered in selecting forages for livestock. This study was conducted to determine effects of N and irrigation treatments on the quality of tall fescue (*Festuca arundinacea* Schreb.) and smooth bromegrass (*Bromus inermis* Leyss.) forage in the Southern High Plains. 'Fawn' tall fescue and 'Southland' smooth bromegrass were grown on Pullman clay loam (fine, mixed thermic, Torrertic Paleustoll) under N rates of 0, 168, 336, 504, and 672 kg ha^{-1} $year^{-1}$ on three water regimes: W-1, a moderate (about 50-cm) and W-2, an adequate (about 100-cm) irrigation water level, both distributed for season-long production, and W-3, a moderate (about 60-cm) irrigation level distributed for cool-season forage production. Forage was harvested and analyzed for N, P, K, Ca, Mg, NO_3^- and in vitro dry matter disappearance (IVDMD). Nitrogen fertilization increased N, K, and NO_3^--N in both forages. The increased K levels increased the K/(Ca + Mg) ratios. Less marked effects of N included slight increases in IVDMD in both grasses, increases in Ca and Mg, and decreases in P in tall fescue but not in smooth bromegrass forage. The total N and NO_3^--N were lower and the Ca and Mg were higher in forage from W-2 than in that from W-1 and W-3. With N rates through 336 kg/ha, NO_3^--N remained below the 2,000-ppm level considered harmful to livestock. Forage P and IVDMD were not affected by differences in irrigation. Although smooth bromegrass was superior to tall fescue in N, K, and Ca concentrations and in IVDMD, N fertilization at levels high enough to produce satisfactory yields increased the K/(Ca + Mg) ratios to levels considered critical for induction of grass tetany. With pure stands of smooth bromegrass, supplemental feeding of Mg would be necessary. Tall fescue contained more Mg than did smooth bromegrass, and its K/(Ca + Mg) ratios were favorable. Without P fertilization, feeding supplemental P would be necessary with both forages. Surface-applied feedlot waste, at N rates equivalent to those applied as NH_4NO_3, was less than one-half as efficient as NH_4NO_3 in increasing N in forage, but it increased P to levels satisfactory for nutrition of mature cows. Both irrigation adequacy and grass species must be considered in fertilizing for maximum production of high quality forage.

Additional index words: *Festuca arundinacea* (Schreb.), *Bromus inermis* (Leyss.), K/(Ca + Mg) ratios, Nutrient uptake, Forage quality, Southern High Plains, Feedlot waste.

BOTH quantity and quality must be considered in selecting forages for livestock feed. In a preceding paper (6), we reported the effects of three irrigation regimes and five N rates on the yield and water-use efficiency of tall fescue (*Festuca arundinacea* Schreb.) and smooth bromegrass (*Bromus inermis* Leyss.). In this paper, we will report effects of the same irrigation regimes and N rates on the quality of these two forages.

Wedin (17) reviewed the literature on fertilization of cool-season grasses. He stated that the percentage of N in grass forage can range from less than 1.5 for N-deficient, mature grasses to several times more. Dotzenko (5) found that 717 kg of N $ha^{-1}year^{-1}$ increased the N concentration of smooth bromegrass from 2.2 to 3.4% and that of tall fescue from 1.8 to 2.9%.

Reid et al. (14) found that N fertilization increased K and Ca concentrations but reduced P concentration in tall fescue forage. High levels of N application increased Mg concentration somewhat.

The in vitro dry matter disappearance (IVDMD) of tissue is an indicator of forage quality. Rehm et al. (13) found that fertilization with N and P had no consistent effect on IVDMD percentage of mature forage. Other researchers (3, 7) have shown that stage of maturity rather than applied fertilizer has a major influence on IVDMD of cool-season grasses.

In addition to increasing total N in plant tissue, N fertilization increases NO_3^--N levels; thus, there is some concern about NO_3^--N poisoning when high rates of N are used. Researchers do not agree on what constitutes acute or chronic levels of NO_3^--N in forage. Suggested values range from 670 ppm (16) to 2,000 ppm (8). Crawford et al. (4) pointed out that intake, level of feeding, and animal condition should be considered in deciding if a forage is potentially harmful.

Nitrogen fertilizer may increase the potential for grass tetany (2, 10). Nitrogen increases K uptake but affects Ca and Mg uptake less; thus, it increases the K/(Ca + Mg) ratio. It is generally recognized that forages with K/(Ca + Mg) ratios greater than 2.2 tend to result in a greater incidence of grass tetany (2).

The purpose of this study was to determine the effects of N and irrigation treatments on the quality of tall fescue and smooth bromegrass forage in the Southern High Plains.

MATERIALS AND METHODS

'Fawn' tall fescue and 'Southland' smooth bromegrass were grown on Pullman clay loam (fine, mixed thermic, Torrertic Paleustoll) under five N rates and three irrigation regimes. Nitrogen rates were 0, 168, 336, 504, and 672 kg $ha^{-1}year^{-1}$ as ammonium nitrate (NH_4NO_3). In a companion study, animal waste from a cattle feedlot was applied at rates of 336 and 672 kg of N $ha^{-1}year^{-1}$. The three irrigation regimes were W-1, a moderate (about 50-cm) and W-2, an adequate (about 100 cm) irrigation water level, both distributed for season-long production and W-3, a moderate (about 60-cm) irrigation level distributed for cool-season forage production. The companion study with animal waste received irrigation treatment W-2. On W-1 and W-2, forage was harvested when the grasses headed in the spring and at three subsequent approximate 6-week intervals. W-3 was scheduled to be harvested twice annually at times corresponding to the first and last harvests on W-1 and W-2. However, one and two additional harvests were made in

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Table 1. Nitrogen fertilizer, harvest date, and irrigation effects on nutrient concentrations, digestibility, NO_3^--N concentration and K/(Ca + Mg) ratios in tall fescue and smooth bromegrass forages. Average 1974–76.

Variable	N	P	K	Ca	Mg	IVDMD†	NO_3^--N	K/(Ca + Mg)
	%						ppm	
N rates								
kg/ha								
0	1.73	0.18	2.47	0.44	0.18	57.62	210	1.25
168	2.01	0.16	2.72	0.44	0.19	58.83	180	1.55
336	2.45	0.16	2.96	0.44	0.20	59.82	510	1.87
504	2.73	0.16	3.07	0.45	0.20	59.86	1540	1.90
672	2.96	0.17	3.12	0.46	0.21	59.13	2600	1.90
L.S.D. (0.05)	0.08	0.01	0.07	0.01	0.01	0.87	180	0.05
Harvest								
1	2.09	0.19	2.49	0.32	0.13	61.87	690	2.05
2	2.50	0.16	3.05	0.47	0.21	56.75	1370	1.67
3	2.48	0.16	3.10	0.46	0.22	55.72	1370	1.66
4	2.43	0.17	2.79	0.52	0.23	61.87	600	1.40
L.S.D. (0.05)	0.11	0.01	0.13	0.02	0.01	1.07	103	0.08
Grasses								
Fescue	2.24	0.17	2.66	0.43	0.24	56.59	990	1.44
Brome	2.51	0.17	3.07	0.46	0.16	61.52	1030	1.95
L.S.D. (0.05)	0.04	NS	0.05	0.01	0.01	0.49	114	0.05
Irrigation treatments								
W-1	2.49	0.17	2.89	0.44	0.20	59.09	1130	1.68
W-2	2.22	0.17	2.89	0.46	0.20	58.58	680	1.71
W-3	2.42	0.17	2.83	0.44	0.19	59.47	1220	1.68
L.S.D. (0.05)	0.08	NS	0.01	0.01	0.01	NS	89	NS

† IVDMD data are for 1974 and 1975 only.

1974 and 1975, respectively. A complete description of the study and yield data are reported in the accompanying paper (6).

Forage samples from all harvests in all years (1974, 1975, 1976) were analyzed for N, NO_3^--N, P, K, Ca, and Mg, and samples from 1974 and 1975 were analyzed for in vitro dry matter disappearance (IVDMD). Total N was determined by the Kjeldahl method modified to include nitrate (1). Nitrate-N was extracted with distilled water and determined by the method of Kamphake et al. (9). Samples were wet-ashed (triple acid digest) and P was determined by the amononaptholsulfonic acid method[3] and K, Ca, and Mg were determined by atomic absorption spectroscopy[4]. The IVDMD was determined by a modification of the method of Tilley and Terry (15). Average concentration data were determined by summing the products of plot yield × plant composition and dividing by the sums of plot yields. Ratios of K/(Ca + Mg) were calculated on an equivalent basis.

RESULTS AND DISCUSSION

Statistical analyses and interpretation of plant analyses and digestibility data by years showed that the effects of treatments were similar among years. Irrigation treatments varied some among years (6) but those variations had only minor effects on plant nutrient composition and digestibility. In most instances, the two grasses responded similarly to N and irrigation treatments so the data presented in Table 1 are averages over grass species, irrigation treatments, and years. Notable exceptions to similar response are described in the text.

Nitrogen Percentage

Fertilization with N increased N concentration in forage of both grasses on all three irrigation regimes. The increases were generally linear with some "leveling off" at the higher N rates on W-1 and W-3 (data not shown). Average N concentrations were lower at first harvests than at succeeding ones. These lower concentrations probably resulted from higher forage yields (more dilution of the N available) and from the forage being more mature at first harvests.

With feedlot waste, N levels were highest at the second harvest and intermediate at the first and third harvests. They dropped markedly at the final harvest (data not shown). The N levels at fourth harvest may have been low because available N from the manure was used up. Smooth bromegrass was higher in total N than tall fescue. The forage of both grasses produced on W-2 was significantly lower in N than that produced on W-1 and W-3. The higher forage N concentrations on W-3 as compared to W-2 resulted from the N applications on W-3 preceding first and last harvests being double those on W-2. Except at first harvests in 1974 and 1975, growth on W-1 was limited by drought and as a result, forage N levels were higher than those on W-2 and usually similar to those on W-3. The N level in forage grown on the 336-kg-N/ha manure treatment was about the same as that in forage grown on the check treatment while levels in forage grown on the 672-kg-N/ha manure treatment were intermediate between those in forage from the 168-kg and 336-kg-N/ha NH_4NO_3 treatments (data not shown).

Phosphorus Percentage

The data, averaged over irrigation treatments and grasses, shows that N fertilization decreased P concentration of the forage. However, data for individual grasses on separate water levels showed that N fertilization did not affect forage P levels on W-1 but, on W-2 and W-3, it decreased P in tall fescue and increased it slightly (only at the high N rates) in smooth bromegrass (data not shown). The decrease in P concentration of tall fescue probably resulted from removal of available P from the soil. This possibility

[3] Technicon Autoanalyzer Methodology. 1968 Industrial methodology INDL-8 Technicon Corporation, Tarrytown, NY 10591.

[4] Revision of analytical methods for atomic absorption spectrophotometry. 1968 Perkin-Elmer, Norwalk, CT 06852.

is reinforced by the following results: (i) overall average P content of forage decreased from 0.18% the first year of the study to 0.14% the third year, (ii) forage from plots fertilized with feedlot waste was considerably higher in P than forage fertilized with NH_4NO_3 (0.23 compared to 0.17), and (iii) the P concentration in forage fertilized at the high rate of feedlot waste was higher than that in forage fertilized at the lower rate (0.25 compared to 0.22). Even though P decreased with continued cropping, yields decreased after the first year, and P concentrations increased with applied P in feedlot waste, we doubt that soil P was low enough for a yield response to P. We attribute the lower yields after the first year to less favorable weather conditions in the two subsequent years. Results of a greenhouse study indicated that yield response to P probably would not bé expected in the field (unpublished data).

A possible reason for the trend toward increased P in smooth bromegrass with higher N rates is that stands of smooth bromegrass on plots with high N were very thick and harvest at the 5-cm height removed all of the green tissue. Regrowth came from new shoots rather than from continued growth of old leaves. New shoots on the N-fertilized plots apparently contained as high or higher concentrations of P than did old shoots on unfertilized plots.

Even though P concentration in the two grasses responded differently to N fertilization, overall average P concentrations of the two forages were similar, the average P concentrations of forages from the three irrigation treatments were also similar. Average forage P levels were highest at the first harvest, lowest at the second and third harvests, and intermediate at the last harvest.

The grasses, when fertilized only with NH_4NO_3, did not contain enough P to meet minimum requirements of mature cows (0.22%) as established by the National Academy of Sciences (11). However, when fertilized with manure, both grasses met the minimum requirements. If feedlot waste were available, a farmer might choose to use it to supply part of the required N and at the same time to supply enough P to raise P to an acceptable level. Inorganic P fertilizer would also increase P in the forage but, unless it also increased yield, its use would not be economically feasible. Feeding P supplements to the cattle would be more economical.

Potassium Percentage

Nitrogen fertilization increased K concentrations of both grasses. Increases were linear between 0 and 336 kg N/ha, but, at higher N rates, increments of applied N affected K concentrations less. Smooth bromegrass had a higher K concentration than tall fescue. The 3-year average data show that forage K concentrations were slightly but significantly lower on W-3 than on W-1 and W-2. The lower K level resulted from the W-3 data being included from harvests when W-3 had not been fertilized nor irrigated during the growth period preceding harvest. (N fertilization increased K levels. Also, K was possibly leached from the dried-up forage). Although feedlot waste is high in K, fertilization with feedlot waste had no more effect on K levels than fertilization with NH_4NO_3 (average 2.69% for two grasses at two manure rates).

Forage K levels were lowest at the first harvest, highest at the second and third harvests, and intermediate at the last harvest. These trends paralleled those of N except that the relative end-of-season decline in K was greater than that in N. The principal difference among years was that average K levels in both forages decreased in successive years.

Calcium Percentage

The average data showed that N fertilization caused a slight increase in Ca content of the forage but that the increase was significant only at 672 kg N/ha. The unaveraged data showed that N fertilizer increased Ca concentrations in tall fescue on W-1 and W-3 but not on W-2. With smooth bromegrass, however, N fertilizer decreased Ca concentrations on W-2 but had no significant effect on W-1 and W-3 (data not shown). The anomalies on W-2, (the lack of a significant effect on fescue and the significant decrease on bromegrass) resulted from comparatively high Ca concentrations in both grasses on the 0 and 168 kg N/ha treatment on W-2. We do not have a plausible explanation for the anomalies. On the basis of results obtained on W-1 and W-3, we concluded that N fertilizer increased Ca concentrations in tall fescue but did not affect them in smooth bromegrass.

Feedlot waste increased Ca concentration in tall fescue but did not affect it in smooth bromegrass (data not shown). Forage Ca was lowest at the first harvest, intermediate at the second and third harvests, and highest at the last harvest. The Ca concentration in smooth bromegrass was significantly higher than in tall fescue. The overall data show that forage Ca was higher on W-2 than on W-1 and W-3, however, this difference resulted from the anomalies mentioned above. If we discount them, water levels did not affect Ca concentration of the forage.

Magnesium Percentage

The average data showed that N fertilization increased Mg concentration in the forage. Data for the individual grasses, however, showed that N fertilization increased Mg concentration in tall fescue but did not affect it in smooth bromegrass (data not shown). Fertilization with feedlot waste had no more effect on forage Mg levels than fertilization with NH_4NO_3. Forage Mg levels were much lower at the first harvest than at succeeding harvests. Tall fescue was considerably higher in Mg than smooth bromegrass. Average Mg levels were only slightly lower on W-3 than on W-1 and W-2, thus irrigation treatments had little effect on Mg levels in the forage.

In Vitro Dry Matter Disappearance

Although there were no significant increases in IVDMD from N fertilization for either grass within irrigation regimes, the data averaged over grass species and irrigation regimes, show a significant increase in IVDMD as a result of N fertilization. The increases were small and when N rates were high enough to produce appreciable yields (336 kg/ha), additional N had no effect on IVDMD. Thus, digestibility is not a consideration in N fertilization. The effect of IVDMD of fertilization with feedlot waste was no different from that of fertilization with NH_4NO_3. Digestibility was higher at the first and last harvests than at the two midsummer harvests. Smooth bromegrass was more digestible than tall fescue. Irrigation regimes did not affect digestibility.

Nitrate Nitrogen Concentration

The average data show that NO_3^--N concentration in forage increased with increasing rates of N fertilization, but the increases were small until N rates reached 504 kg N/ha. Nitrate N concentrations were uniformly low in forage from the plots fertilized with feedlot waste. Average concentrations of NO_3^--N were higher at the two midsummer harvests than at first and last harvests. Concentrations of NO_3^--N were similar in the two grasses. Average NO_3^--N levels in forage from W-1 and W-3 were almost double those in forage from W-2.

Although average concentrations are satisfactory for comparing effects of treatments, they do not report maximum levels attained. Since NO_3^--N levels are rather variable and excess NO_3^--N is toxic to livestock, it is necessary to consider levels attained from specific treatments at individual harvests. A review of the data showed that N fertilizer rates as high as 336 kg $ha^{-1}year^{-1}$ produced forage with NO_3^--N levels below 2,000 ppm on all irrigation treatments. The 504 kg N/ha rate produced forage with NO_3^--N levels above 2,000 ppm at only two of 12 harvests on the W-2 treatment, but both the 504 and 672 kg N/ha rates produced forage containing more than 2,000 ppm NO_3^--N on the W-1 and W-3 irrigation regimes. If forage NO_3^--N levels in excess of 2,000 ppm are harmful to livestock (8), N rates should be limited to less than 504 kg $ha^{-1}year^{-1}$ on fully irrigated smooth bromegrass and tall fescue and to about 336 kg $ha^{-1}year^{-1}$ where irrigation is insufficient for maximum growth.

Tetany Ratio

Concentrations of K, Ca, and Mg were used to compute the ratio K/(Ca + Mg). This ratio is widely accepted for predicting potential grass tetany problems (2). Nitrogen fertilizer increased K/(Ca + Mg) ratios. It increased them more in smooth bromegrass than in tall fescue. The N fertilization increased the ratios by increasing K concentrations without increasing Ca and Mg proportionally. Fertilization with feedlot waste did not increase K/(Ca + Mg) ratios more than fertilization with NH_4NO_3. Ratios of K/(Ca + Mg) were highest at first harvest, intermediate at the midsummer harvests, and lowest at the last harvest. Ratios in smooth bromegrass were considerably higher than those in tall fescue. Average ratios were not affected by irrigation treatments, however, at some individual harvests, ratios tended to be higher on W-1 and W-3 than on W-2 treatments.

As with NO_3^--N, fluctuations in K/(Ca + Mg) ratios may be more important than average data. The data show that the critical ratio of 2.2 was exceeded in both smooth bromegrass and tall fescue at the first two harvests in 1974. The experimental site had been dry farmed before our experiment began and initial soil N levels were high. Thus, at the first harvest, ratios were high in both grasses on all fertilizer treatments. After the second harvest in 1974, ratios exceeded 2.2 only in smooth bromegrass and, except at the first harvest in 1975, only on treatments that received 336 kg N/ha or more. At the first harvest in 1975, smooth bromegrass that received 168 kg N/ha on W-1 and W-3 treatments had K/(Ca + Mg) ratios greater than 2.2 (data not shown).

These results indicate that if the forage is to be utilized by tetany-prone livestock, N rates should be limited to less than 336 kg/ha on well-watered smooth bromegrass and should be further limited if irrigation is inadequate. However, supplemental feeding of Mg might overcome the effects of too high K/(Ca + Mg) ratios and allow heavier fertilization of smooth bromegrass.

Powell et al. (12) found evidence that lambs utilized Ca and Mg less efficiently from tall fescue than from smooth bromegrass. If this is the case supplemental feeding of Mg may also be necessary with tall fescue.

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